WateReuse Quarterly Meeting – October 2020

What Strikes Fear in the Hearts of Water & WW Utilities – Brine Management

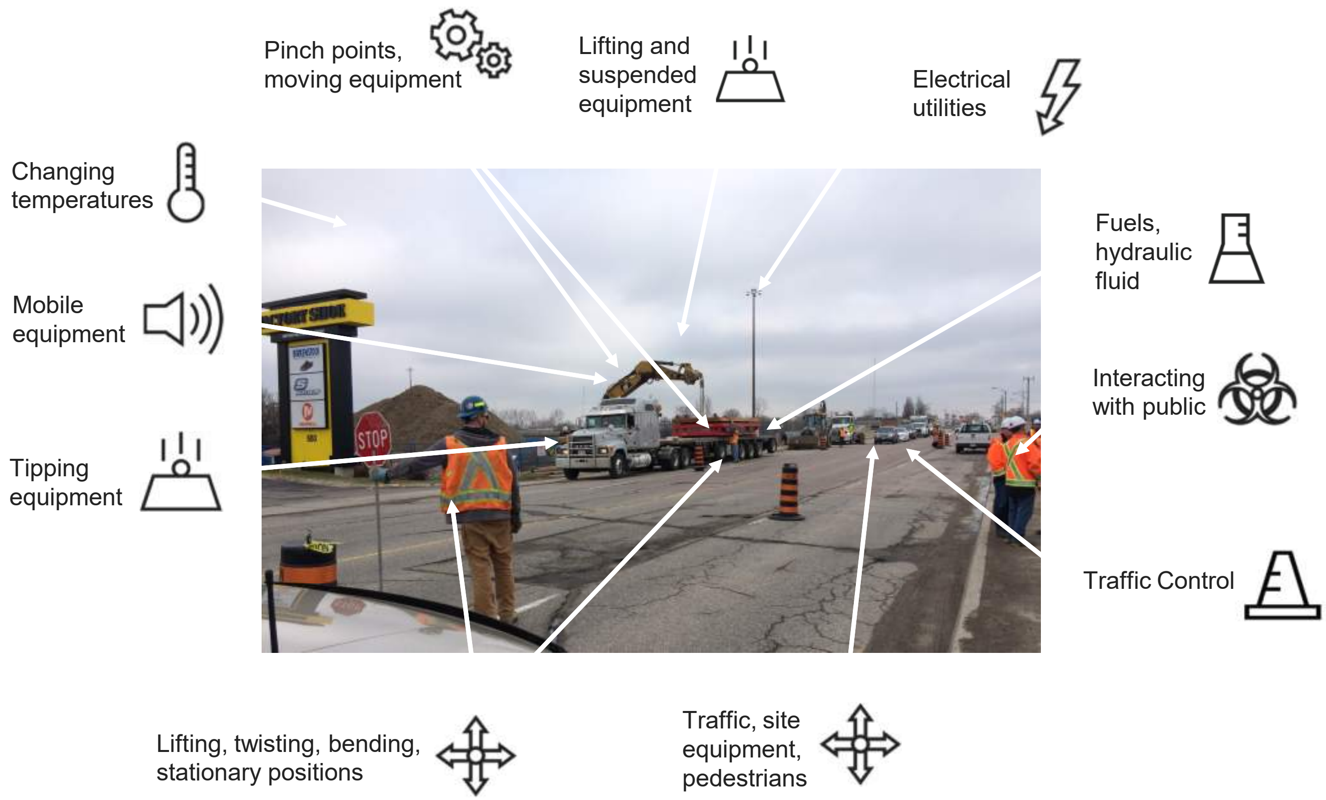
Stantec

Enhanced
Safety Moment

You arrive on site, gear up and start making observations –
What do you see?

Enhanced
Safety Moment

Did you identify more or different energy hazards on this site?



Agenda

1. Safety Moment
2. Where have we been?
3. Where Are We At Now?
4. Where Are We Going?
5. How Can We Get There?

Where have we been?

Arizona Water Supply

Groundwater

- Historically Arizona relied on groundwater
- 200 to over 2500 mg/L in the Salt River Valley
- The Central Buckeye area is now showing signs of exceeding 2800 mg/L along with arsenic & nitrogen
- Tucson groundwater is on the order of 250-300 mg/L

Arizona Water Supply

Surface Water Supply

- Salt River Project is the largest surface water supply system in the state
- Central Arizona Project brought surface water to augment groundwater
  - direct use
  - recharge

Arizona Water Supply

Effluent

- In the 1990s, effluent was considered perfect for purple pipe
- Recharged effluent is now a significant part of the water portfolio
- The focus is now to put this higher water to the best use for each water system
  - To recycle,
  - to recharge, or
  - to directly reuse

100-yr Assured Water

Low Hanging Fruit is In Use

- As development has increased, we find we are looking at lower water quality groundwater; particularly in the West Valley
  - Nitrogen, Arsenic, Selenium, TDS
- Common treatment techniques create a brine stream that is problematic for inland states
- What is the next source of water?

Central Arizona Salinity Study

"…eventually it will become necessary to release salt-laden water from the Maricopa and Pinal units to maintain a salt balance in those areas"

CAP Planning Report, U.S. Bureau of Reclamation, 1948

BUREAU OF RECLAMATION

Central Arizona Salinity Study

- 1.5 million acre-feet
- 1.35 million tons of salt
- SROG Cities in coordination with USBR sponsored the Central Arizona Salinity Study (CASS)

Central Arizona Salinity Study

Part 1 – Characterize Nature of Salinity Problem – 2003

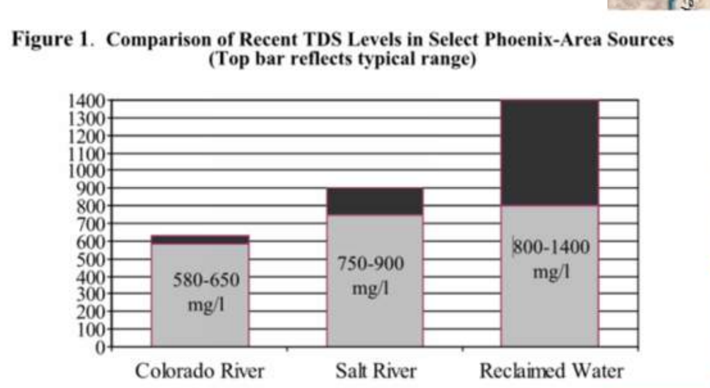
- Where the salts come from
- Where they end up
- Short- and long-term impacts
- Add stakeholders

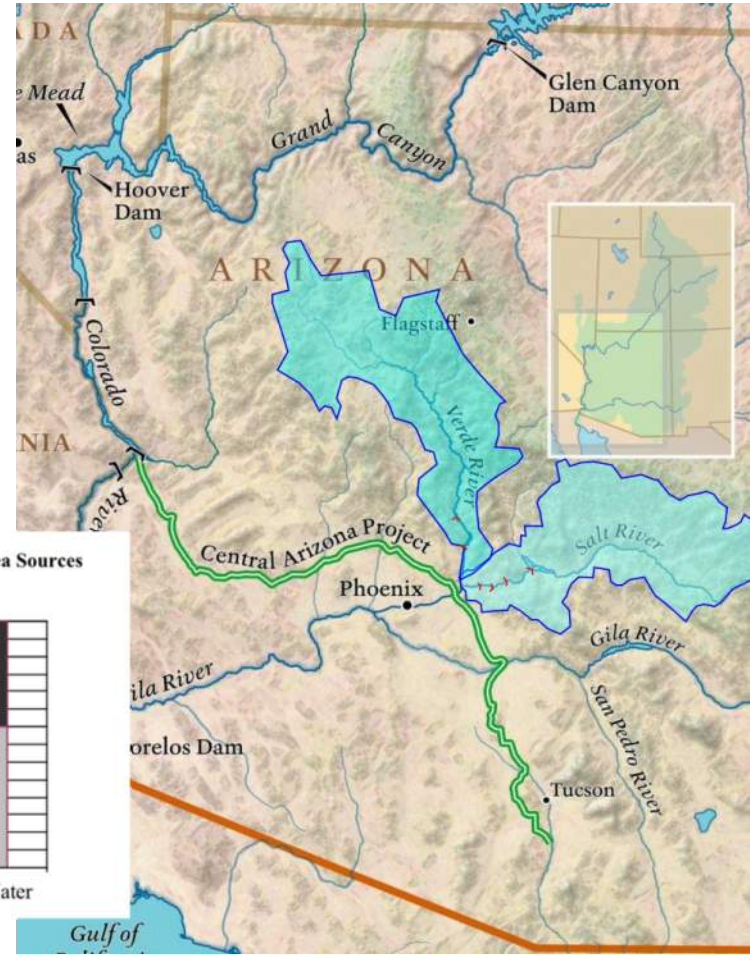
Chandler, Goodyear, Peoria, Surprise, and Tucson, Buckeye, Gilbert, Arizona-American Water Company, Arizona Water Company, and Queen Creek Water Company

CASS – Part 1

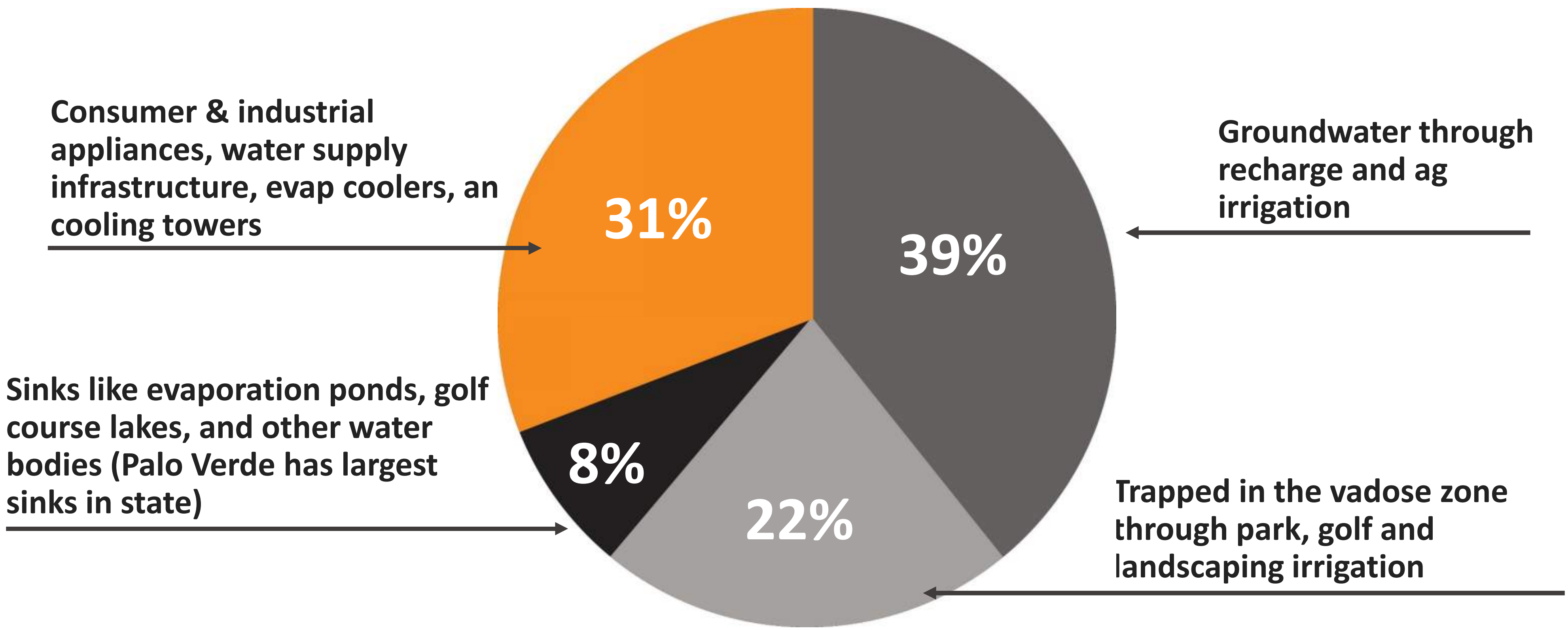
Where are the salts coming from?

- Colorado River
  - Ag return flows
  - Range land runoff
  - Large salt basin in Colorado at the headworks
- Salt River
  - Natural springs
- Recycled Wastewater
  - Water softeners
  - Ag fertilizers
  - Food waste





CASS – Part 1: Where does the salt end up?



CASS – Part 1

What are the impacts?

- CASS Part I reported estimated
  - $30M in damages
  - against a $93.6B Phoenix Metro economy
- That seems low even for that era

Central Arizona Project

Part 2 – Identify and Evaluate Solutions – 2006

- Manage salinity contributions for sources

- Manage the brine “concentration” from treatment

CASS – Part 2

What are the options?

- Colorado River Basin Salinity Control Program
- Public Outreach
- Limiting Salinity Entering Sewers
- Brackish Water Desalination

CASS – Part 2

What are the options?

- Effluent Desalination for Reuse / Recharge
- Improving Concentrate Management Technologies
- Improving Desalination Technologies
- Future Actions for Central Arizona
  - Public Outreach
  - Explore salinity control in WWTPs
  - Research & pilot studies

CASS – Part 3 – 2010

Strategic Options for Brine Management for the Valley of the Sun

1. Pipeline to Yuma
2. Pipeline to Evaporative Ponds in Desert
3. Brine Concentrator / Evaporation Ponds
4. Softening / 2nd RO / VSEP / Evaporation Pond
5. Wetlands w/ Surface Discharge to Gila River
6. Pipeline to Deep Well Injection Site

Alternative Comparison 10 mgd (millions of dollars)

10 MGD	Pipeline to Yuma	Evaporation Pond	Brine Concentrator	Soften/ RO/ VSEP	Wetlands Surface Discharge	Injection Well
Capital	$266.11	$651.69	$272.71	$286.56	$150.22	$ 114.46
O&M	$ 0.62	$ 3.50	$ 29.75	$ 6.90	$ 1.75	$ 11.31
Annualized	$ 14.92	$ 40.26	$ 44.40	$ 22.30	$ 10.37	$ 17.46

2010 / 2011Wetland Study in Goodyear

- Goodyear's RO facility discharges brine to the WRF
- Conducted a Concentrate Management Wetlands Pilot Project
- Several constituents were reduced in the pilot study:
  - Arsenic
  - Selenium
  - Chromium
- TDS was not removed
- Full Scale Facility still an option in future

And then came the 2009 Financial Crisis

- Water Utilities seemed to go into hibernation
- Additional discussion was tabled for many years

Where are we at now?

And then came drought in California & Texas!!

- Direct Potable Reuse moved to the forefront
- Direct Potable Reuse is made into beer!!!
- The public appears to think this might be ok.

Arizona Refocuses

- Focus on water supplies returns
- Moratorium on DPR is removed
- Guidance for DPR & regulations is produced
- In 2015, Governor announces water initiatives
  - Planning Area Process
  - Governor's Water Augmentation Council
- Groundwater Law is updated
  - 2025 effluent recharge sunset clause is eliminated
  - Effluent credit is increased from 50 to 95%
- ADEQ requesting primacy for Deep Well Injection

Goodyear

- Historically relied on groundwater
- Constructed an RO facility
- Discharge the brine to the WRF
  - Noted in CASS Part 3 as the short-term Easy Button
- Brine is impacting the WRF
- Brine is impacting effluent discharge and solids permit compliance
- Solution?
- Colorado River Water!!!


Source: Jacobs DB Team

Buckeye

- Central Buckeye groundwater is high in arsenic, nitrates, and TDS
- Treatment options include RO with brine discharge to:
  - WRF
  - Palo Verde
  - brine ponds
  - or softening & concentrator
- Drilling wells in specific locations w/ arsenic treatment

East Valley

- Scottsdale operates an advanced water treatment facility constructed in 1998
- 23 MGD with average flow at 14 MGD
- 23 golf courses receive water from the campus
- Recharged over 65B gallons by 2018
- Over the course of time TDS to the golf courses has become an issue
- Palo Verde provides a unique Arizona Approach to salinity management

NWRRDS

Northwest Recharge, Recovery and Delivery System – Metropolitan Water District, Marana, & Oro Valley

- Tucson Area GW is 200 mg/L
- CAP averaging 650 mg/L
- Recharging since 1990s
- Using Soil Aquifer Treatment to reduce TOC, pathogens, & larger particles in top 6”
- However, TDS, ions, pollutants flow through
- MWD plans to blend with GW to reach 400 to 450 mg/L

Where are we going?

GWAC Desalination Committee Update

- WateReuse November 2018
  - Bob Lotts; 2018 Chair
  - Philip Richards; 2020 Chair

MISSION STATEMENT

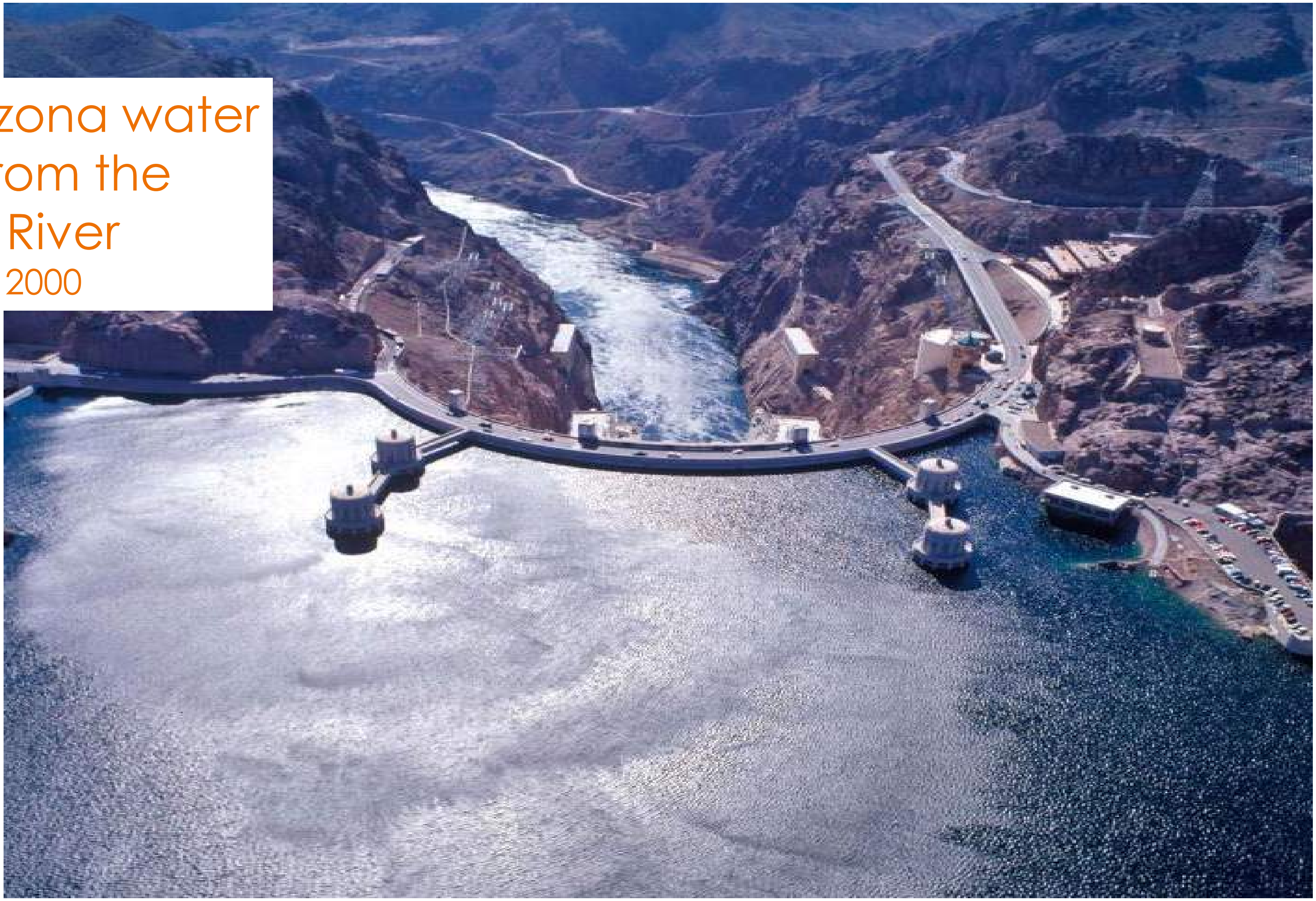
To explore opportunities for in-state desalination with a focus on brackish groundwater and effluent supplies.

Areas of interest:

- In-State Water Resources
- Technology for Desalination
- Cost
- Energy Requirements (Carbon Footprint)

40% of Arizona water supply is from the Colorado River

Lake Mead in 2000

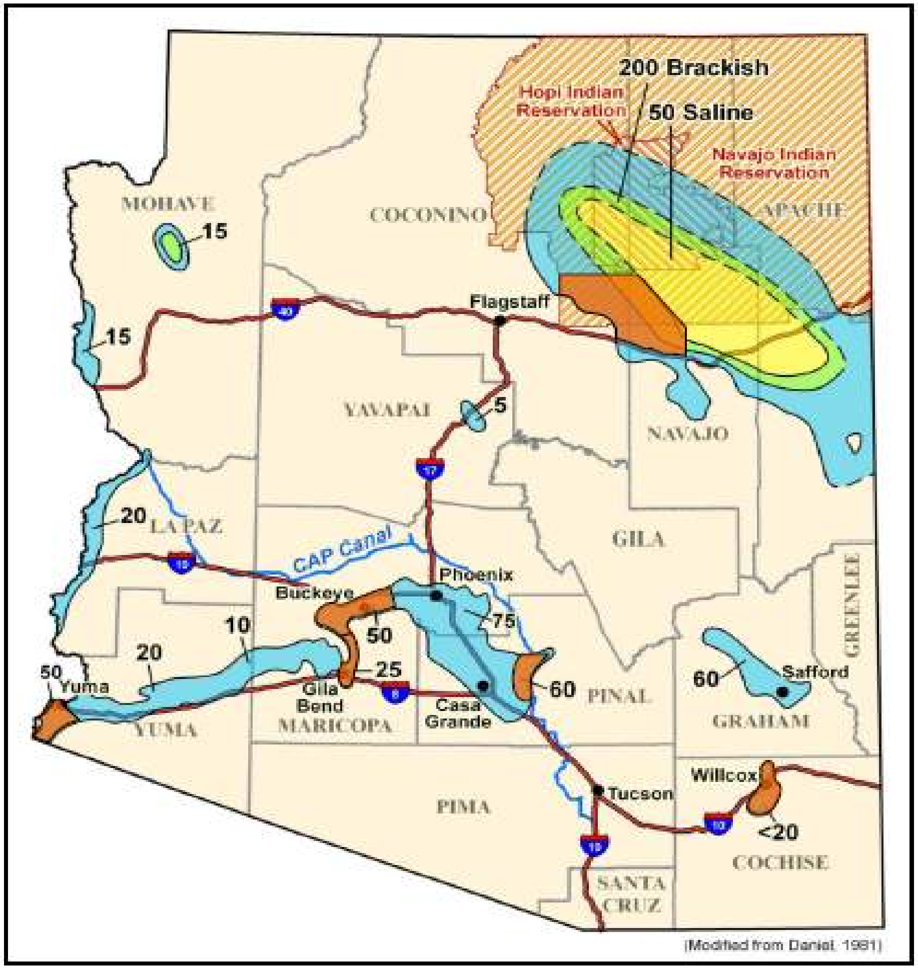


Arizona's water allocation first to be cut in shortage

Lake Mead in 2015

Areas identified for Study

Areas for Further Investigation



- Buckeye Area
- Gila Bend Basin
- Yuma Mesa / Yuma Valley
- Picacho Basin
- Winslow-Leupp Area
- Willcox Playa Area

EXPLANATION

20 Millions of Acre-feet Brackish Groundwater in Storage

Total Dissolved Solids, in mg/l

- 1,000-5,000
- 5,000-10,000
- >10,000

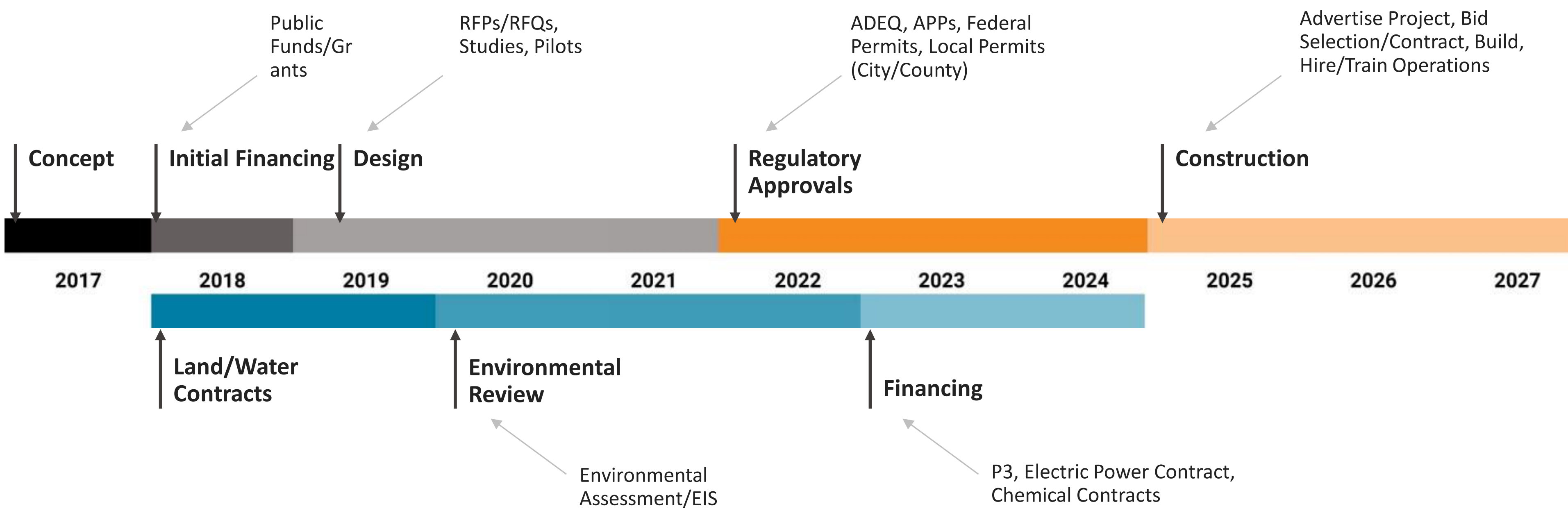
Summary

Site	Brine Disposal Challenge	Cost	Future Status
Yuma Brackish Groudwater Mound	Low	$600 - $1200/af	Colorado River benefits Mexico USBR Coordination
West Salt River Valley (Phoenix AMA) Buckeye Area	3,000 afy brine High Cost	$600 - $1200/af	Designation uncertainty
Yuma Non-Groundwater through YDP to Bypass Drain (Yuma Groundwater Basin)	Low	$400-$500/af	Mexico
Winslow-Leupp Area (Little Colorado River Plateau)	1000 afy High Cost	$600 - $1200/af	Unresolved Federal Groundwater Rights
Gila Bend (Gila Bend Groundwater Basin	High Cost	$600 - $1200/af	Transporting to Phx AMA not currently allowed
Wilcox Playa (Wilcox Groundwater Basin)	High Cost	Not Available	Transporting to Sierra Vista not currently allowed
Picacho-Eloy Area (Pinal AMA)	High Cost	$600 - $1200/af	Transporting to AMA not currently allowed

2018 Next Steps

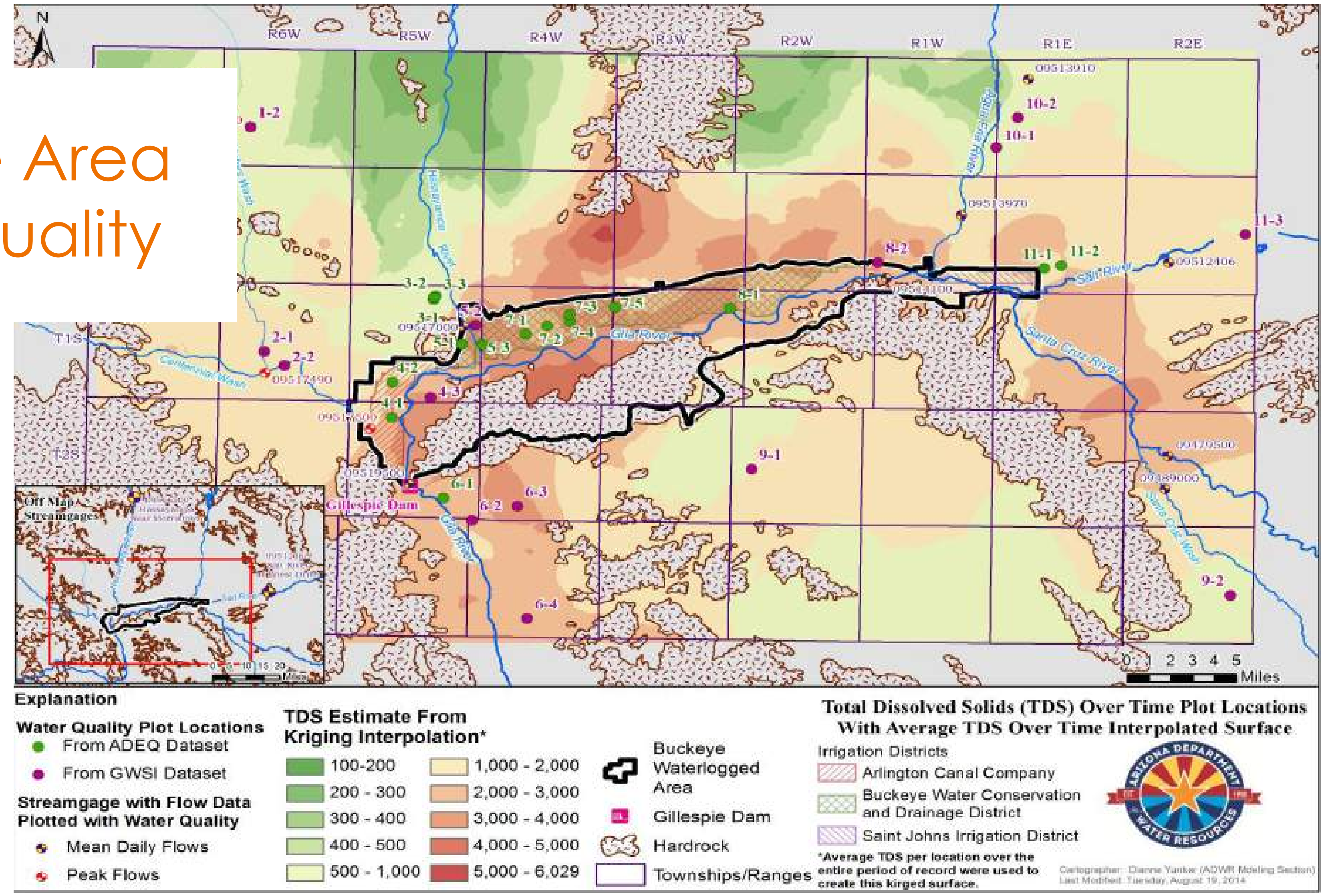
- Stakeholder Engagement
  - Met w/ Yuma Representatives in 3/2018
  - West Valley City Representatives attended Desalination Committee Meeting in 4/2018
  - Need to continue discussions w/ West Valley Cities
- Work w/ ADWR on Regulatory Challenges
- Make Recommendations to GWAC

Desalination Project Timeline



Buckeye Waterlogged Area

Buckeye Area Water Quality



Deep Well Injection

- ADEQ requesting primacy of Underground Injection Control
  - Draft rules published in 2019
  - Updated rules to be published this week
  - Expecting primacy in 2022
- At present, this is an existing permitting process in AZ through EPA
- There are 3 Class 1 Wells in Arizona
- Primacy will streamline the APP and Well permitting process
- Prohibition on hazardous waste injection, but not other injection
- May require Aquifer Exemption Permit

Deep Well Injection

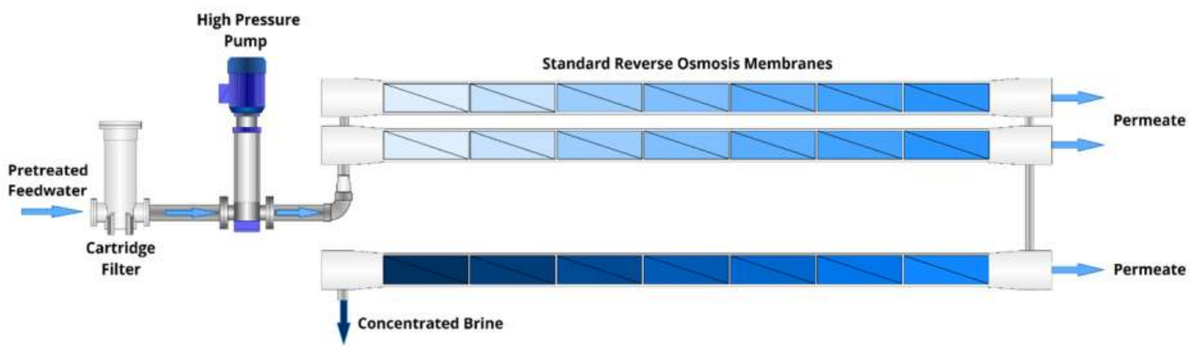
- Permitting & implementation of deep well injection
  - Robust site conceptual model
  - Significant site characterization efforts
  - Reliable model to project aquifer interactions under current and future conditions
  - Coordinated efforts between stakeholders
  - Technical and economic feasibility
  - Well cased off through drinking water aquifer
  - Monitoring wells

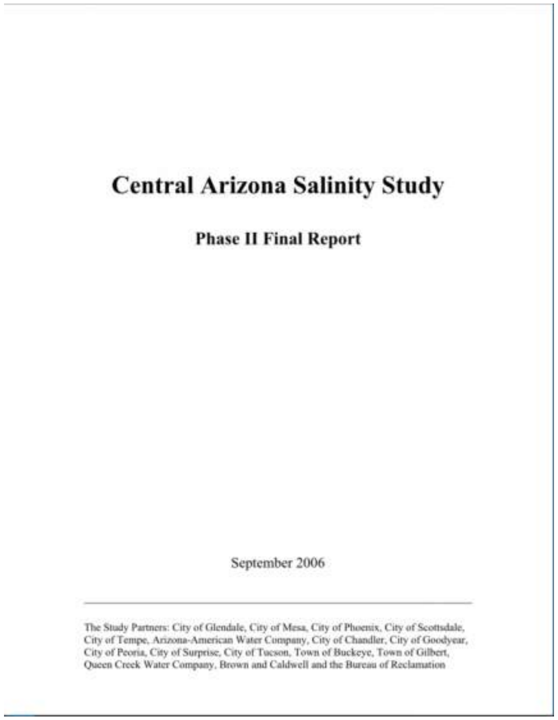
What cool technology will solve the problem?

How can we get there?

CASS Takeaways

- Capital and operating costs too high for most options
- Water resource losses are too high at 15%. Losses need to be between 5 and 10%
- No single technology will meet all applications
- Emergent technologies offer hope but are not yet proven




Central Arizona Salinity Study

Phase II Final Report

September 2006

The Study Partners: City of Glendale, City of Mesa, City of Phoenix, City of Scottsdale, City of Tempe, Arizona-American Water Company, City of Chandler, City of Goodyear, City of Peoria, City of Surprise, City of Tucson, Town of Buckeye, Town of Gilbert, Queen Creek Water Company, Brown and Caldwell and the Bureau of Reclamation

The database has grown

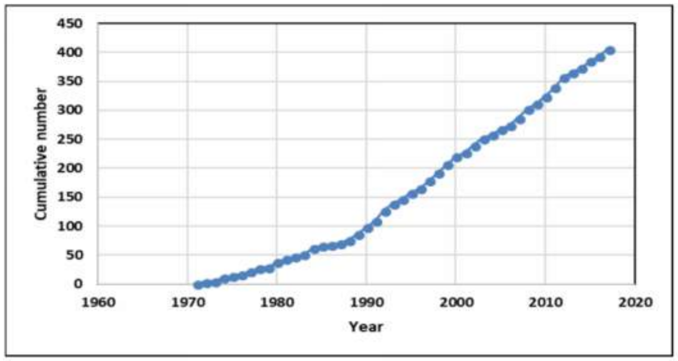


Figure 1.—Cumulative number of U.S., municipal desalination plants.

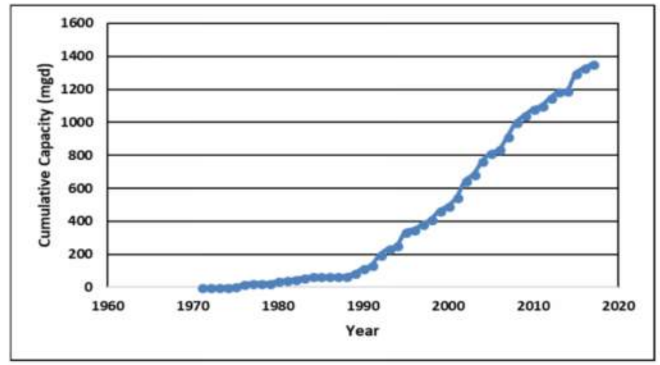


Figure 2.—Cumulative capacity of U.S., municipal desalination plants (in million gallons per day [mgd]).

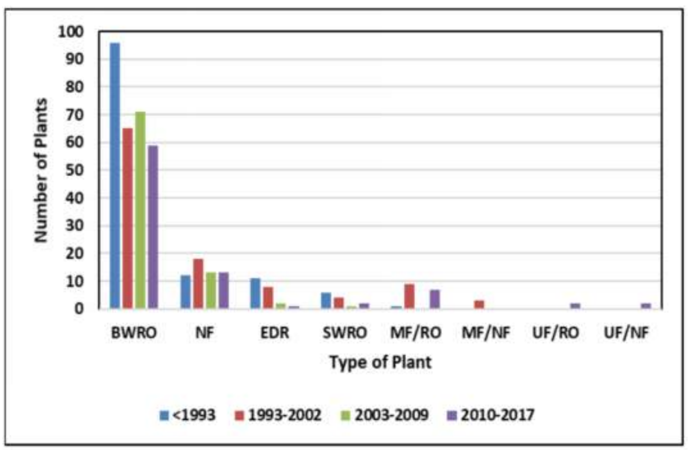


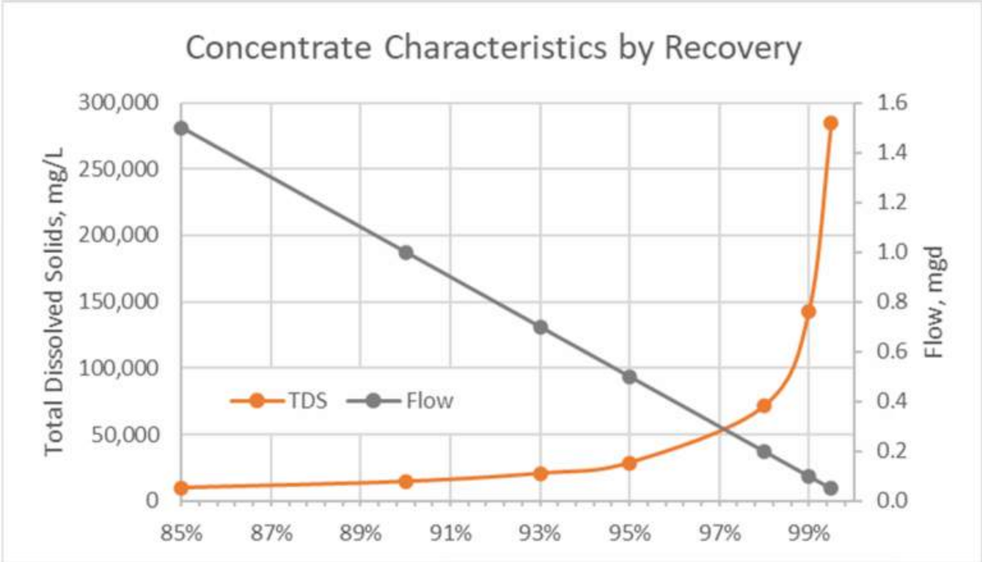
Figure 3.—Number of U.S. municipal desalination plants by membrane type and time period.

Source: Mickley (2018). Updated and Extended Survey of U.S. Municipal Desalination Plants.

- Approximately 406 facilities through 2017 of 0.25 mgd or greater.
- Approximately 150 plants since mid 2000s
- Approximately 600 mgd since mid 2000s
- Most were some form of RO

Shifting the ZLD Paradigm

Parameter		Concentrate	Conc. TDS	Cum. Conc. Flow Red.	Cum. TDS Incr.
	Unit	mgd	mg/L		-
	Feed	10	1,500		-
Concentrate TDS or Flow as a Function of Recovery	85%	1.5	9,575		-
	90%	1.0	14,325	-33%	50%
	93%	0.70	20,432	-53%	113%
	95%	0.50	28,575	-67%	198%
	98%	0.20	71,325	-87%	645%
	99%	0.10	142,575	-93%	1389%
	99.5%	0.05	285,075	-97%	2877%



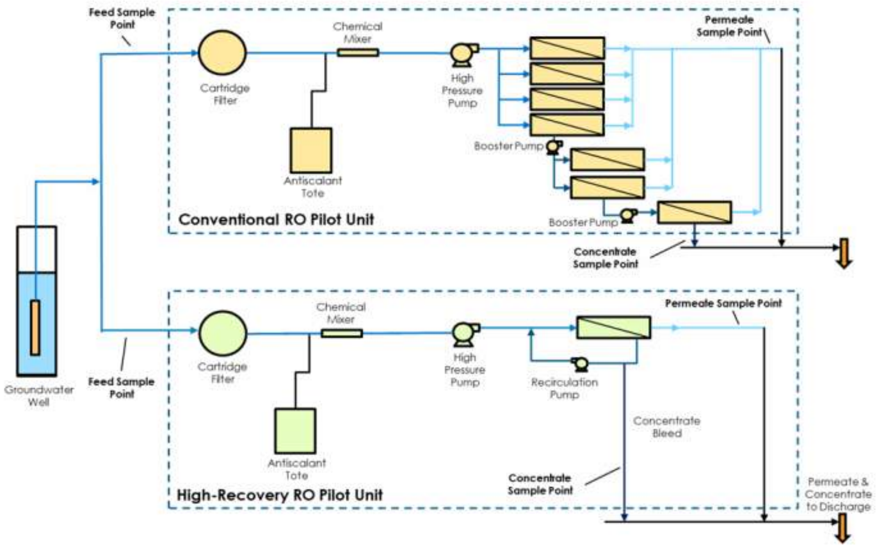
High Recovery and ZLD Options

Technology	Application	Typical Energy Use		Salinity Limit, mg/L	Typical Recovery	Typical Product TDS, mg/L	Maturity
		kWh/m³	kWh/kgal	mg/L		mg/L	
Brackish RO	Product	1.5-2.5	6-10	75,000	70-85%	< 10	●
Seawater RO	Product	2-6	8-23	75,000		< 10	●
HERO	Product				90-98%	< 10	● → ●
Desalitech	Product				75-98%	< 50	● → ●
MaxH20	Product				90-98%	< 10	●
ROTEC	Product				85-90%	< 10	●
MVC Brine Concentrator	Concentrate Recovery	20-39	75-150	250,000	75-98%	< 10	●
Brine Crystallizers	Concentrate Recovery	52-66	180-250	300,000	~100%	30-50	●
ED/EDR	Concentrate Recovery	7-15	26-57	100,000	97-98%*	10,000	●
Membrane Distillation	Concentrate Recovery	22-67	83-254	200,000	98*	-	●
Forward Osmosis	Concentrate Recovery	21	80	200,000	60-65%	-	●

* Combined recovery with RO.

Table adapted from Tong & Elimelech (2016) and AWWA M69 (2019).

West Valley Piloting



Adelman et al (2020). Exceeding 90% recovery with conventional and closed-circuit RO: results from parallel pilot systems.

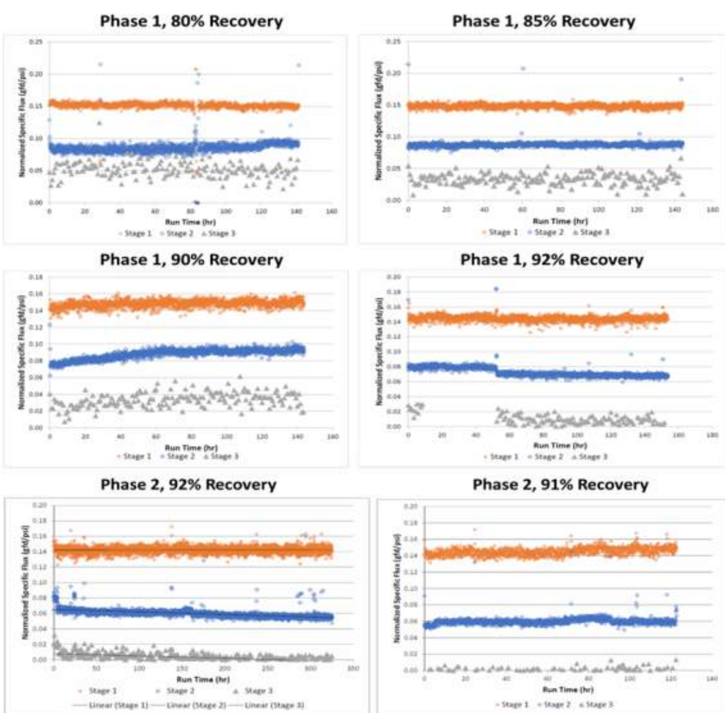
- Parallel 3-stage conventional and high recovery RO processes
- High TDS – 2,700 mg/L
- Modeling predicted a theoretical max recovery of 94%

Parameter	Conventional	High-Recovery
Pressure Vessel Array	6:4:2	1
Pressure Vessel Length	3 elements	3 elements
Element Model	Toray TMG10	Dow BW30XFRLE-400
Element Dimensions	4" diameter; 80 ft^2	8" diameter, 400 ft^2
Feed Flow Rate	26.6 – 30.5 gpm	9 gpm (CC mode)
Recovery	80 – 92%	80 – 95%
Permeate Flow Range	20.6 – 24.5 gpm	6.3 – 9 gpm (CC mode)
Concentrate Flow Range	2.1 – 6.0 gpm	20 gpm (PF mode)
Average Permeate Flux	10.3 – 11.3 gfd	7.6 – 10.8 gfd (gross)
Pre-Filter Rating	20/1µm (dual graded)	20/1µm (dual graded)
Chemical Feeds	Antiscalant (1-3 mg/L)	Antiscalant (1-3 mg/L)
High Pressure Pump	30 gpm, 7.5 HP	30.4 gpm, 10 HP
Booster Pumps	5 HP @ St 2, 2.5 HP @ St 3	-
Circulation Pump	-	22 gpm, 1 HP

Both were great options

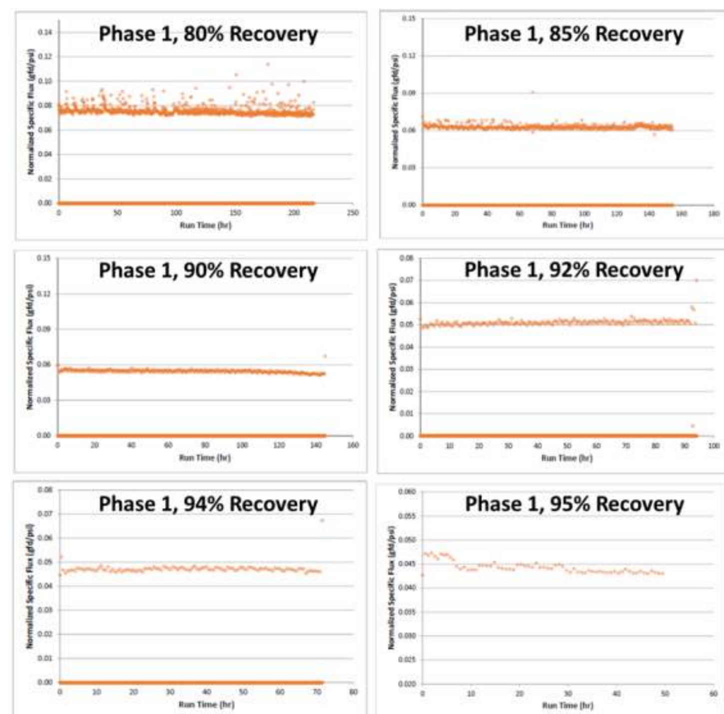
Pressure and Normalized Flux for Conventional RO Train:

- Consistent normalized flux during Phase 1 with no notable decline.
- Measurable downward trend in normalized flux at 92% recovery, during Phase 2.
- Lower but consistent normalized flux after recovery returned to **91%**.

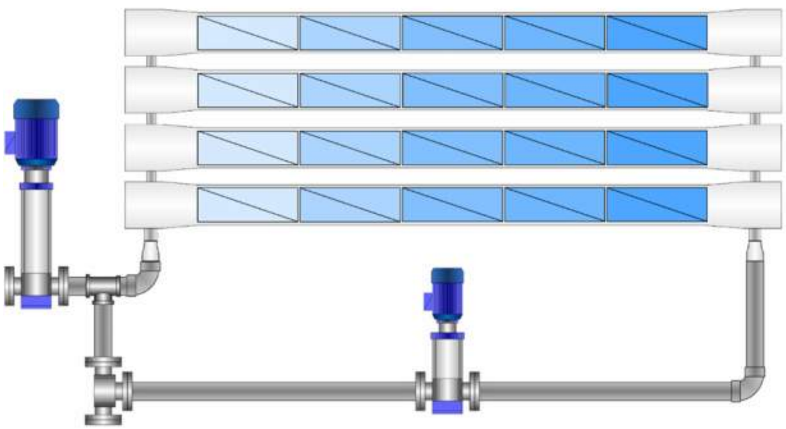


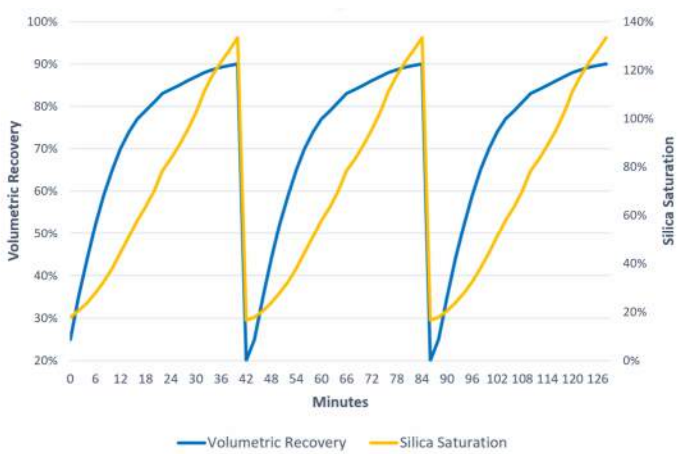
Pressure and Normalized Flux for High-Recovery RO Train:

- Consistent flux at all recovery points during Phase 1 up to **94%**.
- Noticeable flux decline was observed at 95% recovery.



Closed Circuit RO (Desalitech/Dupont)

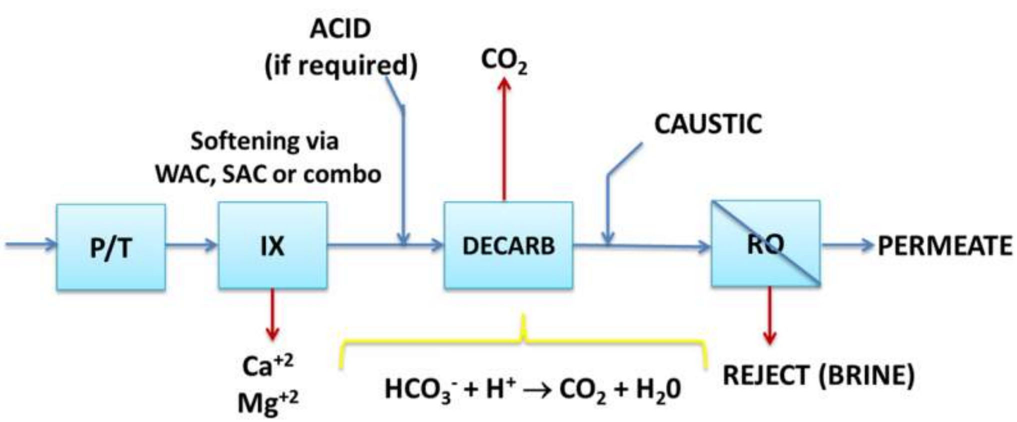




- Semi-batch process
- Single stage RO
- Uses cross flow filtration and fouling / scaling kinetics to optimize
- Two operating modes: closed circuit (100% recovery) and plug flow (waste)
- Patented and Dupont will begin licensing to OEMs
- Founded 2008
- First US Install 2012
- 250 installations as of 2019
- Similar RO flux and specific energy

Graphics courtesy:

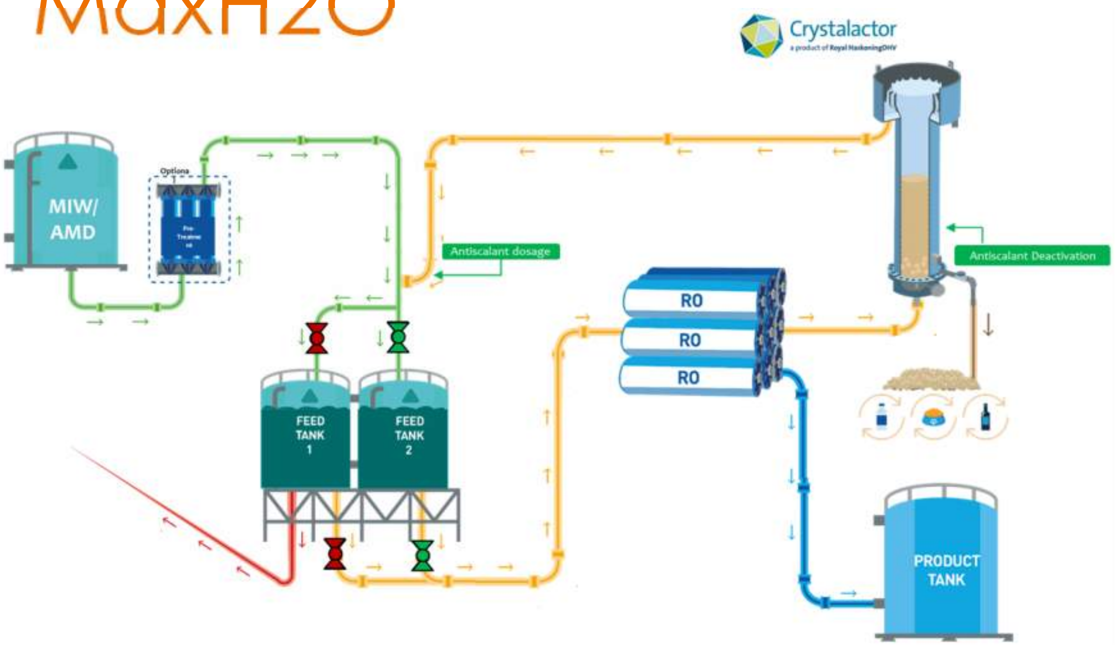
HERO™

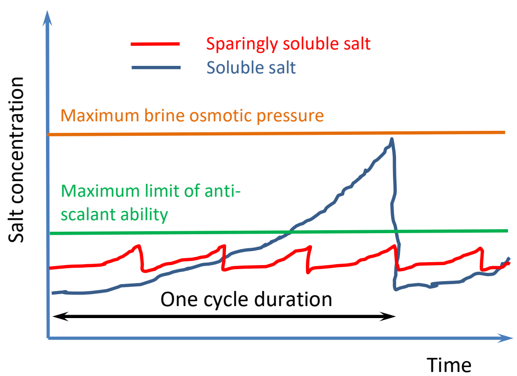


Graphics courtesy: Aquatech

- Pretreatment to remove hardness and operate at high pH (>10.5)
- Multi-stage RO
- Process started in the 90s
- 150+ Installations as of 2019 (40 for Aquatech)
- Patented and now licensed
- Similar to higher flux depending on feedwater characteristics
- Biological fouling reduced
- Cleaning frequency extended
- Reject brine is softened

MaxH2O





- Semi-batch process
- Single stage RO
- Integrated brine softening / salt precipitation post-treatment
- 100% production mode followed by waste cycle
- Process published in 2016
- Partnership with Royal Haskoning DHV (70+ installs since 1986)
- First US municipal facility 2021
- Similar flux and specific energy anticipated
- Precipitation dewater to 90%
- Reject brine is softened

Graphics courtesy:

CASS Updates

- Capital and operating costs too high for most options
- Water resource losses are too high at 15%. Losses need to be between 5 and 10%
- No single technology will meet all applications
- Emergent technologies offer hope but are not yet proven

Policies, Regulation, Regional Options, The Road Map

How can we get there?

Enviro Water Minerals ZLD in El Paso

- Process1.3 mgd concentrate
  - TDS: 13,000 mg/L
- or 1.3 mgd of raw brackish water
  - TDS: 2,500 mg/L
- Products:
  - Potable-Quality Water (TDS<700 mg/L)
  - Caustic Soda (50% Concentration)
  - Hydrochloric Acid (35% Concentration)
  - Gypsum (high purity, 100% Soluble)
  - Magnesium Hydroxide (98% Purity, 56% Solid)

EWM Lessons Learned

- Facility is not operating yet
- Going from bench studies to full scale
- Private funding requires quick paybacks

Arizona's Forward Thinking

- Coordinate Stakeholders
- Identify technologies
- Evaluate regulatory limitations
- Identify funding

Arizona’s Forward Thinking

- Combination of advanced and conventional options
- Maximize AZ Options
  - Deep well injection
  - Evap ponds
  - Coordinate w/ Palo Verde

Acknowledgements

- John Kmeic at Tucson Water
- Philip Richards at APS
- Bob Lots (ret) at APS
- City of Buckeye
- Barbara Chappell at City of Goodyear
- Gretchen Erwin at City of Goodyear
- Wally Wilson at Metropolitan Domestic Water Improvement District
- Randy Shaw at USBR Brackish GW National Desalination Research Facility
- Dr. Malynda Cappelle at UTEP
- Scott Reinert at El Paso Water
- Desalitech
- Aquatech
- IDE
- Daniel Reeder at ADEQ
- Jon Rezabek at ADEQ UIC@azdeq.gov

Personal History Story

Guy Carpenter suggested at one point that the Anasazi's disappeared from the area without there any appearance of war or other outward influence. They just appear to not be here and then new people are here. He thought maybe they salted themselves up with their farming operations.

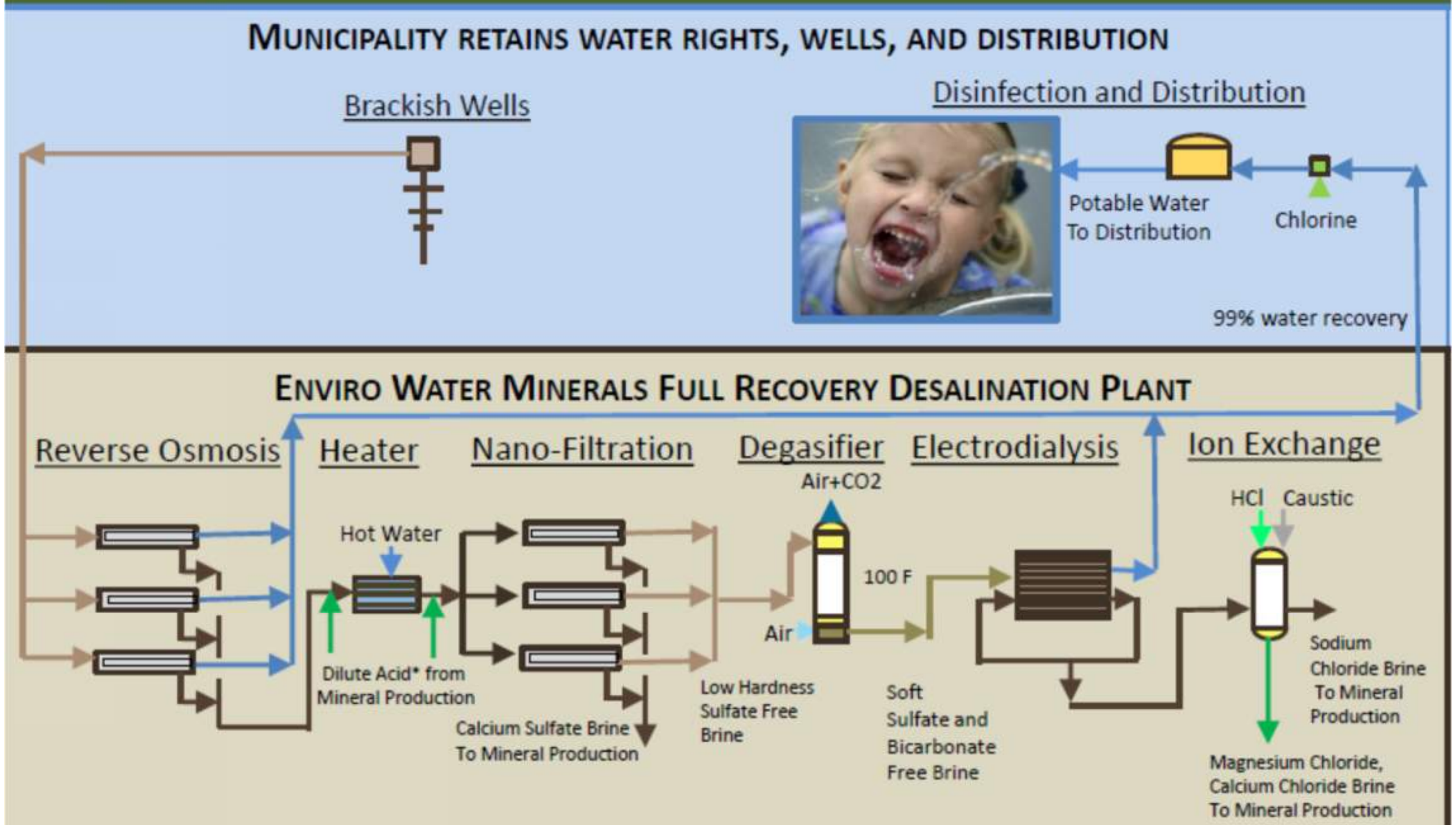
We see that occur in other parts of the West. In Grant County, Washington State, the federal government built three huge irrigation districts bringing nearly 3 x the CAP water to central Washington. Over time, this irrigation led to high groundwater in the lower elevation areas. Now there are wells to pump the groundwater to keep the land in production.

We see these unintended consequences all through human history if we take the time to look.

TDS in Arizona, may be our unintended consequence.

Full Recovery Desalination Plant

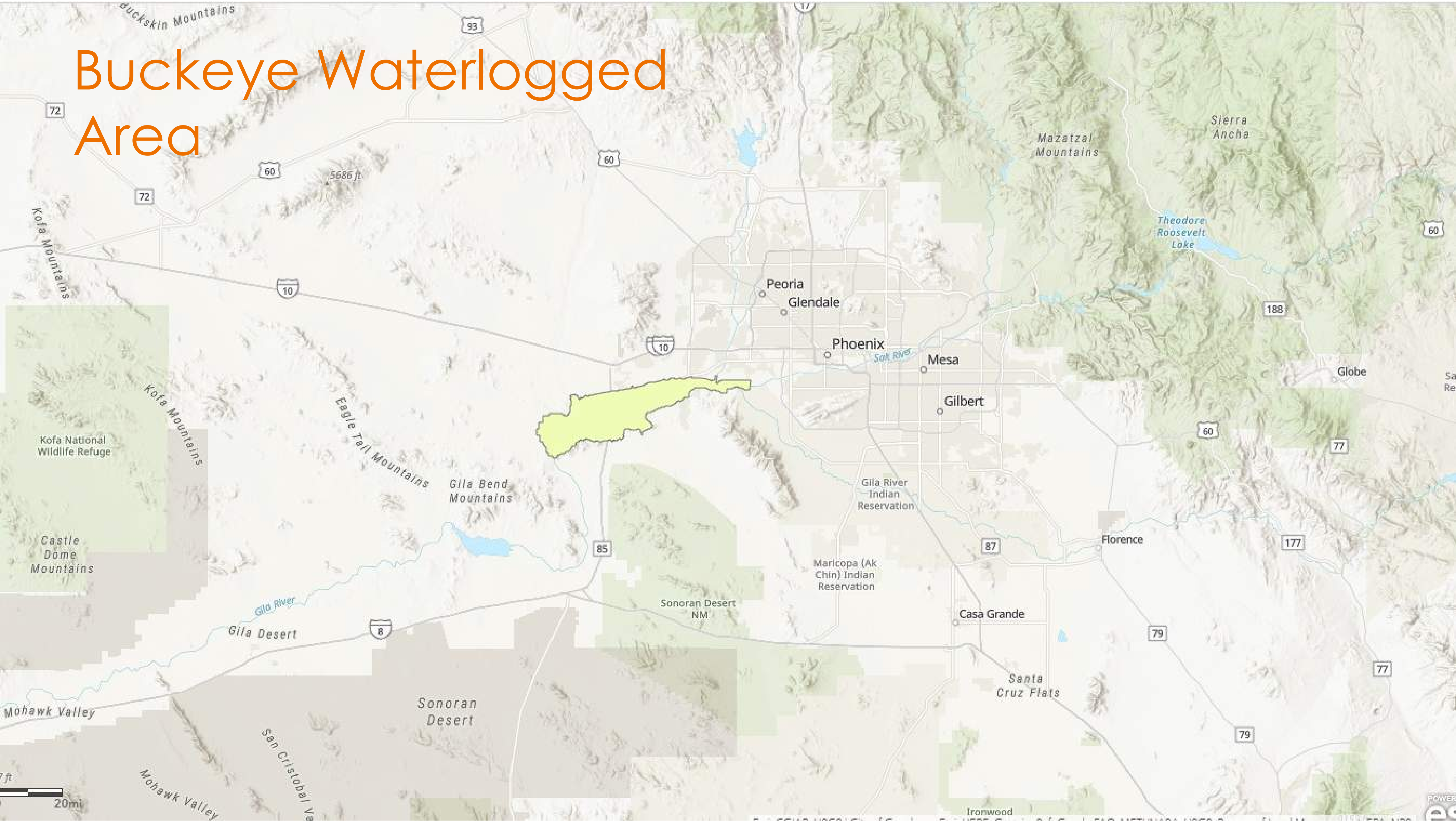
EWM
ENVIRO WATER MINERALS COMPANY



* NSF 60 certified acid provides additional product water and silica desaturation

Buckeye Waterlogged Area

Buckeye Waterlogged Area




Buckeye Waterlogged Area
Tonto National Forest
Theodore Roosevelt Lake
Peoria
Glendale
Scottsdale
Phoenix
Mesa
Gilbert
Globe
Florence
Sonoran Desert NM
Casa Grande

Buckeye Waterlogged Area Could be a Supply for Buckeye, Goodyear